Pulse Power Systems and Diagnostics for the Fixed Hybrid Armature Railgun

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Plasma physics within the confines of railgun science is not well understood. Since plasmas and "restrike" are primarily responsible for preventing ultrahigh velocities (UHV) in such guns, there is a great need to predict and control that behavior.

Given the potential role of UHV railguns in equation of state (EOS) studies, we must regain our expertise in all aspects of railgun science. Working toward this goal we rebuilt the Fixed Hybrid Armature Railgun (pictured in the previous report in this volume), implemented advanced diagnostics, and began to recreate past experiments. Experimental data will be provided to the UHV railgun project and applied to the validation of a new plasma model in ALE3D, a 3-D multi-physics computational platform.

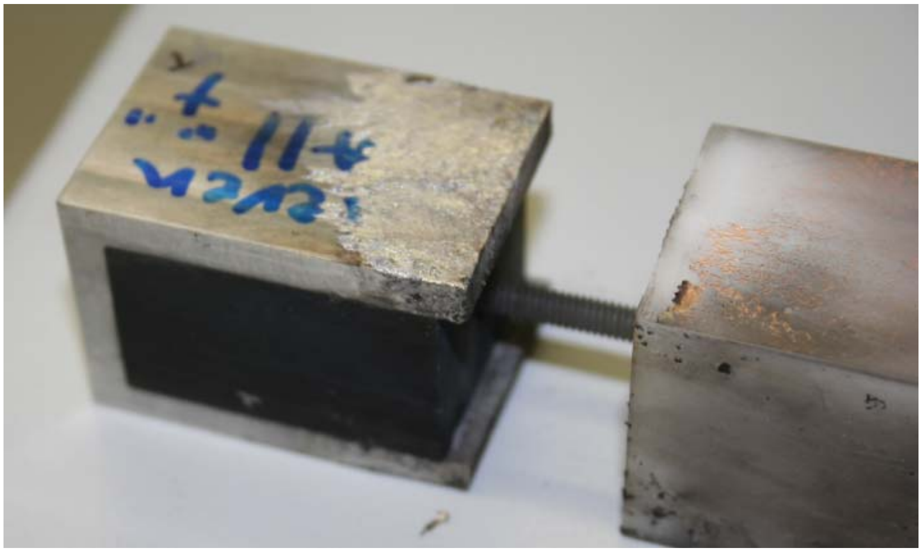

Figure 1. Post-shot picture of a small hybrid armature that had been held stationary between rails by the rod and stop block. The plasma brush creation caused material ablation, evident on the armature.

Project Goals

The primary goal of this project is to provide diagnostic data with sufficient resolution and relevance to validate a plasma model in ALE3D that is applicable in the railgun regime. To achieve this, we assembled the railgun and configured a testbed for the application of high-energy pulsed power and sensitive diagnostics. We intend to perform multiple experiments, with multiple parameter modifications similar to those performed a decade ago, along with new configurations.

Relevance to LLNL Mission

This project directly addresses diagnostic systems for a railgun testbed and also addresses the feasibility of UHV railguns, which would be well suited to shock physics and EOS studies. Both of these goals are expressed as immediate needs for LLNL, and impact all pulsed power programs at LLNL.

FY2007 Accomplishments and Results

By leveraging legacy hardware from the early 1990's, we assembled the Fixed Hybrid Armature test facility and performed the first experiment in late FY2007. In this experiment, plasma brushes were formed from exploding aluminum foils, which then provided a current path through the armature. Peak current was 290 kA and a post-shot inspection of the armature exhibited evidence of plasma brush creation (Fig. 1).

Since the armature was fixed in place, a pseudo-steady state was achieved and diagnostic investigation was simplified. This shot included many diagnostic sensors. Two arrays of five B-dots each were used to measure magnetic fields produced by the plasma. These small loop antennas were oriented with their loop normals orthogonal to the rail magnetic fields, and were thus unaffected by rail current (Fig. 2). The array was used to diagnose plasma currents as a function of position.

Two counter-wound Rogowski coils were positioned around the upper rail for measurement of the total input current, and plasma pressure was obtained with a piezoelectric quartz sensor (Fig. 3). The rail voltage was measured with a differential probe, and the pulsed power system included additional current and voltage diagnostics.

Fiber optic pressure and optical emission sensors were used as a proof of concept in determining plasma characteristics, and will be implemented fully in future experiments. The experiment produced a total of 45 files of data that we are currently analyzing. A sample of B-dot data is shown in Fig. 4.

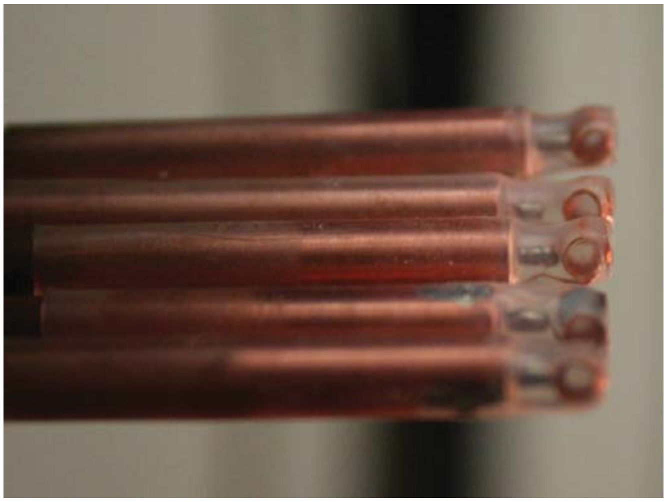

Figure 2. One of two B-dot arrays positioned to sense plasma magnetic field generation. These are 15-turn loop antennas with an ID of 0.063 in. and a measured effective area of 33mm.[2] They are soldered to semi-rigid coax and encased in transparent shrink-wrap.

Figure 3. Piezoelectric quartz pressure sensor with integrated electronics that has a form factor capable of pressure measurements up to 30 kpsi. This post-shot photograph shows evidence of hardened copper and aluminum debris on the sensing diaphragm which is just 0.1 in. in diameter.

Related References

1. Drobyshevski, E. M., *et al.*, “Physics of Solid Armature Launch Transition into Arc Mode,” *IEEE Transactions on Magnetics,* **37**, 1, pp. 62-66, 2001.
2. Hawke, R. S., *et al.*, “Summary of EM Launcher Experiments Performed at LLNL,” *IEEE Transactions on Magnetics*, **22**, 6, pp. 1510-1515, 1986.
3. Hawke, R. S., *et al.*, “Plasma Armature Formation in High Pressure, High-Velocity Hydrogen, Starfire: Hypervelocity Rail Gun Development of High Pressure Research,” *IEEE Transactions on Magnetics,* **25**, 1, p. 219, 1989.

FY2008 Proposed Work

We intend to continue experiments on the Fixed Hybrid Armature Railgun. Data from FY2007 will be processed and analyzed, providing guidance for additional shots. Fiber optic diagnostics will be implemented, allowing faster response times and less physical intrusion, thus providing additional precision to ALE3D validation.

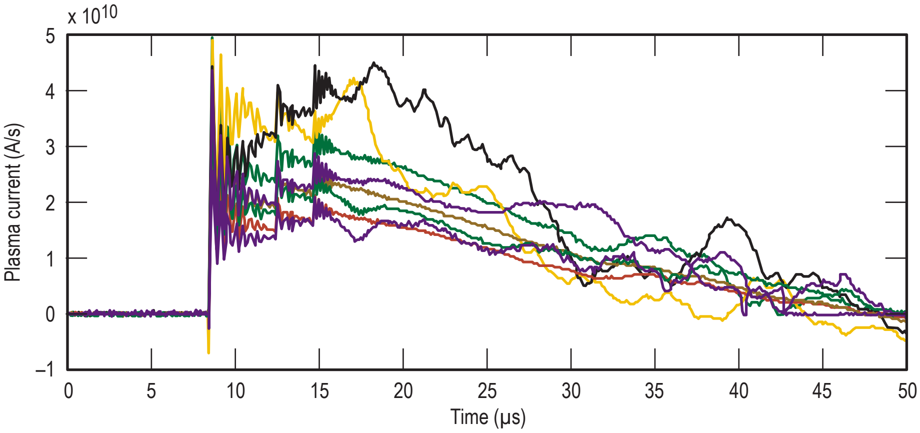

Figure 4. Eight traces of scaled B-dot data from an early experiment shot. The initiation of each of the three capacitor banks is evident at 8.5, 12.5, and 14.7 μs, followed by cable ringing.